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INVENTORY OF MILLS AND TAILINGS IN THE UPPER ANIMAS RIVER WATERSHED: LOCATIONS, PHOTOGRAPHS, AND INFLUENCE

by

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INTRODUCTION

Mill tailings are a potentially important source of acid and metals in watersheds because these materials are finely ground, are commonly permeable, minerals in them are reactive, and typically are placed in or near wetlands and (Plumlee, 1999). Because basic information on the status and location of mills and their tailings is sparse in published literature and nearly absent in electronic databases, an effort was made to locate them in the Animas River watershed. The information in this report is neither complete nor quantitative, but should be useful to persons concerned with the influence of historic mining on the Animas River watershed.

Some definitions are needed. A mill is a structure where ore is processed to concentrate minerals and metals of economic value. Included in the processing are numerous stages and appropriate equipment for grinding the ore and separating minerals or metals by physical or chemical methods. Physical methods generally are based on a physical property such as density or magnetic susceptibility, and in the study area typically included jig tables to recover heavy minerals like gold or galena. Chemical methods require that the ore minerals be dissolved, and this generally involves the use of cyanide. There also are chemical-physical processes that do not dissolve the minerals but utilize chemicals to do the work, including amalgamation (mercury is used to collect gold on its surface) and floatation (soapy reagents are used to pick up minerals according to special surface properties).

Tailings are here defined as the refuse after mill processing of *ground* ore (Thrush, 1968). The term 'tailings' is used by geologists and engineers in many other ways to connote the leavings or low-value materials from mining, but here is the key distinction is the ground condition: these materials are typically fine sand size, but can be coarser than beach sand in some early stamp mills, and can include finer material of clay size that some call 'slimes'. The porosity of tailings is highly variable, depending on the ore mineralogy, processing, and placement of tailings. Some are highly permeably like clean beach sand, but others can be nearly impermeable because of clays, and not uncommonly the porosity is variable from layer to layer. Because most mills process the ground rock with water, the tailings leaving a mill are a viscous fluid like wet concrete in a cement mixer and can be poured, pumped through a pipe, or run through a sluice. It is much cheaper to process wet tailings downward, thus tailings are almost always topographically below the mill structure and in some places are carried in pipes or sluices for thousands of feet to an impound or 'pond.' The pond allows the tailings to settle and the water to be collected and commonly recycled. Impounded tailings are generally damp, compact, and quite cohesive. The cohesiveness of old tailings is a significant issue because they tend to appear to be strong, but in practice are susceptible to wind and

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stream erosion or even catastrophic failure by liquifaction (when the 'solids' become a viscous liquid and flow like pancake batter).

Tailings tend to be placed on mill patents (private property with use justified for this purpose and larger in size than a mine patent), but in places tailings may be placed on public lands adjacent to the mill patent. The land status of mills and patents in the study area is not well known to the author, and the likelihood of their being on private property has restricted the kinds of observations and sampling that could be done. Most of the sites described here were observed from a distance on public thoroughfares. This restriction limited my ability to identify and characterize mill tailings, which can be difficult to recognize through willows and other riparian vegetation. Locations given in Table 1 are not highly precise as they were measured by standard GPS, extrapolated to the estimated site that could not be visited, and for some localities measured from 1:24,000 scale topographic maps. Chemistry and reactivity of these tailings is discussed elsewhere (Nash, 1999).

Smelters can be sources of contamination, especially from thick and noxious fumes (Nash and others, 1996), but the slag at three smelter sites in this area probably is not a significant problem. Leach tests on slag from this area suggest that very little is soluble (Nash, 1999). However, these and other slags contain several percent lead, copper, zinc, and other base metals which can be mobilized by gastric juices if the slag is ingested. Thus, the slag at the three sites appears to pose little threat to water, but should not be handled or eaten by humans or wildlife.

BRIEF INTRODUCTION TO MILLING IN THE AREA

Changes in mining and milling technology over the years have had important influences on the materials left behind in the mines or placed on dumps and tailings piles. In this region at least four stages of technology can be described:

1). Early stage (1875-1890) small-volume mining of high grade ores: because the associated milling and transportation infrastructure at this time was poorly developed, the ores often were hand sorted to create extremely rich material for direct shipping to smelters. Local smelters were built by several entrepreneurs to treat specific kinds of local ores from the Red Mountain district pipe mines or the more typical vein deposits, but the high lead content defied the crude technology of the time and all failed with little production. Hand sorted ores were carried by mules, or wagons, on crude roads and, after 1882, by trains to efficient smelters in Durango, Denver, and Pueblo. Many of the mills in this era utilized water power. This stage of mining has left a relatively low impact on the environment today because most of the milling and smelting was done elsewhere and not much mineralized waste rock was brought out onto dumps. The mills that operated in this early stage, as in Little Giant Basin and Arrastra Creek, were small stamp mills that were not very efficient at removing much other than gold, and the tailings were discarded in any convenient manner, often directly into streams. Very little remains near these mill sites today. In about 1890 methods were changing, but the price of silver was dropping and this hurt efforts to create better infrastructure.

2). Middle stage (1890 to about 1918), medium-volume mining with larger stamp mills: the mines that survived the silver crash of the mid-1890's or reopened later tended

to be larger and deeper, and often utilized trams to carry ore to protected millsites below treeline. The chief incentive was to locate mills at sites distant from avalanches to minimize risk of injury and damages. Mills were enlarged to 150 and even 350 tons per day capacity (Ransome, 1901; Henderson, 1926); the larger mill throughput obviously created more tailings and there often was little space for the tailings. Electric power was available at some sites, but many mines utilized steam to power their equipment. The mills of this era tended to be down in the main valleys, and most were close to the railroad that ran up the Upper Animas River. Most of the tailings from this period can not be found near the mills and it must be presumed that either they were piped into the creeks, or that the impounds were inadequate to survive floods such as the ones that occurred in 1911 and 1928 (Follansbee and Sawyer, 1948).

3). Late-middle stage (1918 to 1935), flotation mills introduced: infrastructure did not change much, but new technology called 'selective floatation' permitted mills to concentrate sphalerite for profit (earlier zinc drew a penalty), and also other sulfide minerals such as galena and chalcopyrite in separate fractions for higher value when shipped to smelters for refining. This new technology permitted the mining of 'low grade' ores of the type in the Sunnyside mine (Burbank and Luedke, 1968; 1969), and the rate of mining increased accordingly. Use of electricity was now the norm for increasingly large-scale mining. The change in style was first made at the Sunnyside mine and the associated new mill built at Eureka in 1917. In this stage mine tunnels reached many miles in length (some crossing under natural drainage divides), numerous tramways carried ores to centralized mills, and large mine dumps and mill tailings piles were created.

4). Modern regulated stage (1935-1990), controls on tailings: tailings technology changed in 1935 when regulations required that mill tailings be confined to tailings ponds rather than allowed to go into surface streams. An Executive order imposed this regulation to improve the quality of water in streams. The Shenandoah-Dives (Mayflower) mill was a leader in the development of methods to collect tailings, and to separate and recirculate mill water from tailings ponds back to the mills. This is explained well on displays at the tourist stop southeast of the Mayflower mill, created by the Sunnyside Mining Corp. in about 1995. A smaller number of mills operated in this period, the largest by far was the Mayflower mill that processed ore from mines run by the company (first the Shenandoah-Dives complex to the east, then the Sunnyside mine complex to the west), as well as from numerous smaller mining operations on a 'custom' basis. The tailings from some of the mills at this stage created very large, multi-million ton impounds such as at the Mayflower mill and at the Idarado mill in the Red Mountain District. These have been physically stable, with no evidence of significant failure in the Silverton area, but there have been concerns over chemical processes operating in the tailings to leach and mobilize metals into groundwater, which have been addressed by reclamation work in the 1990's. I lack information on the age of many of these impounds and the behavior of the tailings after placement because all are on private property and little is recorded in the literature.

INVENTORY OF MILLS AND TAILINGS

An inventory of mills, or mill sites, and associated tailings because the published literature and electronic databases have incomplete records. Electronic databases, such as those maintained by the USGS and by the former US Bureau of Mines (MAS/MILS) contain reports on less than ten percent of the mills and even less information on tailings.

Tailings are considered to be the important environmental feature because the materials most typically were placed in or close to streams and wetlands. Locating mills in the field often is a first step toward identifying their tailings, or lack thereof. Some of the mills were described in reports (Ransome, 1901; Henderson, 1926; King and Allsman, 1950), most of which I could confirm in the field. A few mills could be identified on topographic maps, and then checked in the field. Some tailings impounds are large enough to be shown on topographic or geologic maps, a great help, but not always reliable because many maps use the same label for mine dumps and placer mine spoil. Information for 51 mill and 23 tailing sites, and 3 smelter sites is given in table 1, and the locations are shown on Figure 2. The number of mills may seem high for such a small area, but really is a minimum estimated because I surely have missed some sites that were burned beyond recognition or which were rebuilt. The number of tailings sites that I list is an even lower estimate of the number originally present because many of the older mills have no visible preserved tailings to report. The volume of tailings that were placed directly into streams or eroded during storm events is difficult to quantify but is one of the most important implications of this study.

PHOTO TOUR OF MILLS AND TAILINGS

Color photos, in digital format, are included to help understand the mills and tailings and the wide disparity in their size and present condition. Most of the structures have collapsed over the years, and many are burned or rotted beyond restoration. Some may question the identification of structures as mills, and I would agree that some could be another variety of mining-related building. However, for more than 90 percent of mills, the multiple-level design (to facilitate gravity feed of materials) is diagnostic. The 75 photos are explained briefly and the user can 'click' on buttons to view the picture using Adobe Acrobat Reader, which is widely distributed as free software.

DISCUSSION OF TAILINGS AND THEIR SIGNIFICANCE

Tailings are a significant legacy of mining. The volume of fine sands produced during milling is proportional to the amount of ore produced, and typically much more abundant than the ore sent away to be refined: from a ton of ore mined, tails commonly are more than 80 percent, to as much as 99 percent, or more than 1,600 pounds per ton.

The total amount of tailings created in the watershed in 125 years of mining is on the order of 16-18 million tons if one extrapolates from the figures for 1873 to 1964 (Burbank and Luedke, 1964). Of this about 12 million tons is reasonably accounted for, mostly in the Mayflower mill impounds (the Sunnyside Mining Co. display near the Mayflower mill states that this mill produced 10 million tons of tailings, most of which appear to be in place). We can make some estimates for time periods:

a). early years: production from 1873-1890 was roughly 150,000 to 190,000 short tons (Henderson, 1926); possibly 10 percent of this is in place near those old mills.

b). middle years: production from 1890-1918 was about 2.5 million short tons; possibly 10 to 20% of these tailings are in place.

c). late-middle years: production from 1918 to 1935 was about 1.5 million short tons; possibly 20 % of these tailings are in place;

d). Modern regulated era: production after the 1935 order was about 10 to 12 million tons; most of these tailings are in place.

These estimates are not precise but are sufficient to suggest that about 3 to 5 million tons of tailings are not accounted for—washed down the minor and major streams. This is qualitatively supported by studies of stream alluvium, and especially sandbar and overbank deposits that visibly display layers of tailings. Detailed studies of alluvium stratigraphy (Vincent and others, 1999) and stream-sediment geochemistry (Church and others, 1997) provide more facts. The scope of this problem is large and quantification is difficult.

This study documents what many specialists know, but is inadequately reported in the literature:

- Tailings typically are placed within 200 yards of streams, and often are in floodplains.

- Some impounds were breached during severe storms, but the evidence is mostly downstream in overbank deposits. In contrast, in other areas such as Nevada, one can see partial remains of breached impounds and track the fluvial tailings down arroyos for 2 to 10 miles.

- The majority of mills were in the Upper Animas River watershed, and these probably produced 80 percent of the tailings by tonnage. Mills in the Mineral Creek watershed had the smallest amount of tailings, possibly about 5 percent of the total. Cement Creek watershed had several large mills, and possibly 10-15 percent of total tailings tonnage.

- The tailings that have been lost to stream drainages are effectively part of the geochemical baseline for the area, similar to clasts of mineralized rocks. The tailings on sandbars, overbank deposits, or mixed in with bed sediments, are very difficult to remove because restoration activities would damage habitat and these activities are very expensive.

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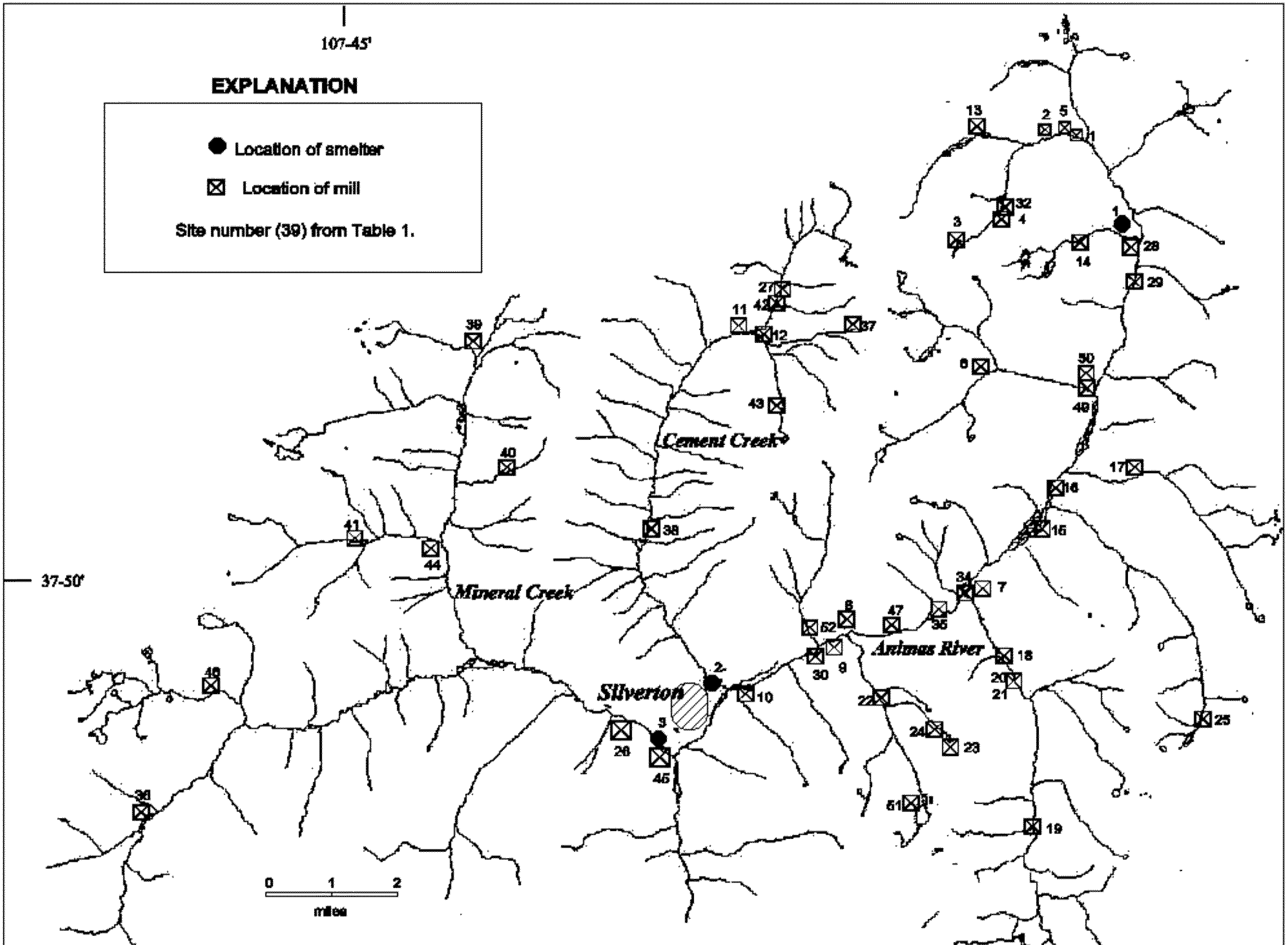

Figure 1: Location of mills and smelters in the Animas watershed, San Juan County, Colorado.

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Table 1: Location and description of mills and tailings in Upper Animas River watershed, Colorado

Site-ID	Map	Name	Ndd	Wdd	MILL	TAILS	COMMENTS
SMELTERS							
NAG170	1	Eclipse smelter	37.9178	107.5592	Y	S	ECLIPSE SMELTER C. 1880, SMALL VOL OF SLAG NEXT TO ANIMAS R
NAG171	2	Greene(?) smelter	37.8200	107.6628	Y	S	SMELTER CEMENT CRK MOUTH; MOD VOL SLAG C. 1890
NAG299	3	Walshe/S. Silverton	37.8078	107.6750	Y?	S	SILVERTON SMELTER, 1 MI WEST; FAIRLY LARGE
MILLS							
NAM103	1	Gold Prince	37.9300	107.5689	Y	N	BIG MILL, TRAMMED ORE FROM GOLD PRINCE; NO TAILS EVIDENT, 30 JIG TABLES
NAM104	2	Bagley	37.9325	107.5783	Y	SM	WOOD MILL, BAGLEY, SMALL TAILS to east
NAM105	3	Mastodon	37.9100	107.5992	Y	SM	SM STAMP MILL, STONE FOUNDATION, TAILS IN CREEK
NAM107	4	Hanson	37.9117	107.5944	Y	SM	SM STAMP MILL, SM TAILS, restored, excellent condition
NAM109	5	Columbus	37.9322	107.5708	Y	NX	SM STAMP MILL EARLY ANIMAS FKS
NAM111	6	Eureka Gulch (Sunnyside)	37.8831	107.5919	Y	NX	MD MILL EUREKA GULCH, SUNNYSIDE EARLY; NO TAILS FOUND
NAM112	7	Pride of the West Mill	37.8394	107.5917	Y	MD	PRIDE OF WEST MILL, HOWRDSVILLE; MED TAILS CONTAINED
NAM113	8	Mayflower mill	37.8283	107.6292	Y	LG	MAYFLOWER BIG MILL HUGE TAILS IMPOUND INTACT
NAM114	9	Silver Lake mill	37.8278	107.6272	Y	NX	BIG CEMENT FOUNDATION,EAST OF MAYFLOWER MILL; NO TAILS
NAM115	10	Lackawanna mill	37.8144	107.6522	Y	SM	LACKAWANNA MILL AND TAILS BELOW
NAM116	11	Mogul-Gold king	37.8908	107.6525	Y	NX	GLADSTONE BIG CEMENT MILL; NO TAILS
NAM117	12	Lead Carbonate New	37.8917	107.6500	Y	N	LEAD CARBONATE MILL PER TOPO; TAILS GONE?
NAM121	13	Vermillion	37.9339	107.5978	Y	SX	CONCRETE REMAINS BELOW DUMP, TAILS S OF ROAD
NAM164	14	Treasure Mtn	37.9142	107.5694	Y	NX	TREASURE MTN MINE AND MILL; COULD FIND NO TAILS IN PICAYUNE GULCH
NAM229	15	Hamlet mill	37.8519	107.5747	Y	NX	CONCRETE AND WOOD, 1 MI N OF HOWDSVL; NO TAILS
NAM230	6	Kitti-Mac mill new	37.8606	107.5706	Y	MD	KITTI-MAC TRAM MILL; TAILS TO SW NAT 101
NAM234	17	Kitti-Mac mill old	37.8622	107.5533	Y	NX	EARLIER KIT-MAC MILL IN MINNIE GULCH; NO TAILS
NAM252	18	Old Hundred	37.8222	107.5861	Y	NX	OLD HUNDRED MILL; TAILS SMALL AS OBSERVABLE
NAM257	19	Highland Mary	37.7878	107.5778	Y	MD	HIGHLAND MARY MILL, STONE FOUNDATION ONLY
NAM268	20	Buffalo Boy(?)	37.8181	107.5819	Y	NX	CONCRETE STRUCTURE ACROSS RD FROM TRAM BUILDING
NAM269	21	Buffalo Boy	37.8197	107.5825	Y	NX	STONE FOUNDATION, BEAMSN STEEL, W OF BUFFALO BOY MINE/TRAM
NAM279	22	Iowa Mill	37.8125	107.6169	Y	NX	CRUDE FOUNDATION, METAL PARTS; TAILS START 100 M TO WEST
NAM291	23	Little Giant, old	37.8042	107.5986	Y	SM	CRUDE FOUNDATION, GRIND WHEELS, TAILS; OLD STAMP MILL
NAM292	24	Little Giant	37.8086	107.6022	Y	SM	LITTLE GIANT STAMP MILL, EXC. PRESERV., STAMPS GONE, SM VOL TAILS BELOW
NAM299	25	Minnie Gulch	37.8133	107.5361	Y	NX	10 STAMP MILL IN GREAT SHAPE; NO TAILS--GONE IN MINNIE CREEK?
NAM302	26	Northstar	37.8069	107.6797	Y	NX	NORTHSTAR MILL, SOME TAILS POSSIBLY ALONG MINERAL CREEK
NAM330	27	Red and Bonita	37.8978	107.6447	Y	NX	RED AND BONITA MILL, VERY FEW TAILS on fericrete terrace
NAM354	28	Burns/Narrows mill	37.9106	107.5561	Y	N	SMALL STONE FOUNDATION, UPPER ANIMAS, ZERO TAILS
NAM356	29	Silver Wing	37.9033	107.5553	Y	N	SILVER WING MILL, ZERO TAILS
NAM363	30	Aspen mill?	37.8244	107.6328	Y	N	MINIMUM REMAINS, FOUNDATION, SMALL MILL ONE LEVEL? NO TAILS
NAM377	32	Sound Democrat?	37.9125	107.5954	Y?	NX	FOUNDATION AND BOARDS NORTH OF M107, JIG TABLE

NAM388 34	Howardsville Mill	37.8372 107.5444	Y	NX	OLDER MILL, NEW RED ROOF, TRAM TO SE; SMALL TAILS
NAM389 35	S Howardsville	37.8339 107.6006	Y	NX	MINIMUM FOUNDATION, TWO? LEVELS, SOME TAILS
NAM399 36	Bandora	37.7869 107.8006	Y	NX	BANDORA MILL, SM CONCRETE FOUNDATION, NO STEEL, NO TAILS
NAM409 37	Lead Carbonate old	37.8908 107.9664	Y?	SX	OLD LEAD CARBONATE MILL, AT MINE, SMALL TAILS NEARBY
NAM414 38	Yukon mill	37.8494 107.6764	Y?	N	BLUE METAL BUILDING, ON SITE OF OLD MILL?
NAM424 39	Silver Ledge	37.8758 107.7264	Y?	N	MINIMUM REMAINS NEXT TO ORE BIN, CHATTANOOGA
NAM509 40	Brooklyn	37.8603 107.7139	Y	SM	SMALL HANDMADE MILL, 70'S? BROOKLYN
NAM524 41	Ruby Trust	37.8447 107.7519	Y	SM	OLD STAMP MILL WITH JIGG TABLES
NAM529 42	Gold King old	37.8969 107.6447	Y	SM	STONE FOUNDATION, TRAM TO EAST, HIGH SULFIDE TAILS ON SLOPE
NAM552 43	Big Colorado	37.8769 107.6464	Y	SX	MILL BOARDS AND STEEL JUNK BELOW ADIT
NAM600 44	Burro Bridge	37.8511 107.7264	?	SX	BURNED BEAMS FOR STAMP, SOME TAILS AND ORE
NAM602 45	Lodore	37.8017 107.6725	Y	MX	LODORE MILL; SMALL TAILS REMAIN
NAM609 46	Ice Lake	37.8117 107.7822	Y	SX	WOODEN BEAM STANDING, 20 STAMPS, QUITE GOOD CONDITION
NAM618 47	Big Giant mill?	37.8294 107.6161	Y	SX	CONCRETE FOUNDATION, STEEL STUFF, AT END OF TRAM TO BIG GIANT MINE
NAM619 48	May not be a mill	37.8269 107.6278	Y	SX	WOOD FLOOR AND BEAMS, AUGER FOR TAILS, SOME TAILS
NAM624 49	Eureka old	37.8803 107.5678	Y	MX	OLD EUREKA MILL, STONE AND WOOD, 50 STAMP?
NAM625 50	Eureka new	37.8808 107.7178	Y	LX	NEW EUREKA MILL, CONCRETE, BURNED, 8-10 LEVELS
NAM641 51	Silver Lake old	37.7916 107.6212	Y	M	LARGE MILL AND TAILS SW OF SILVER LAKE
NAM960 52	Crooke mill	37.8280 107.6350	Y	S?	SITE AS SHOWN BY RANSOME (1901), COVERED BY MAYFLOWER TAILS?
TAILINGS					
NAT101	Kitti-Mack new	37.8536 107.5708	Y	MD	OCHER TAILS FROM KITTI-MAC MILL 200 M TO NE
NAT102	Fluvial tails	37.8728 107.5661	Y	LGX	HUGE TAILS IN ANIMAS FROM EUREKA MILL TO NW
NAT113	Mayflower tails	37.8272 107.6484	Y	LG	THREE IMPOUNDS, RECLAIMED, 10 MILLION TONS
NAT127	Hanson? Demo?	37.9175 107.5900	Y	SM	SMALL TAILS IN PLACER GULCH, FROM ?? MILL
NAT234	Kitti-Mac mill old	37.8622 107.5533	Y	NX	SMALL POCKET OF TAILS IN MILL
NAT258	Highland Mary	37.7886 107.5789	Y	MD	HIGHLAND MARY OCHER TAILS; STABLE IMPOUND IS A SURPRISE
NAT270	Old Hundred	37.8244 107.5864	Y	NX	OCHER TAILS FROM OLD HUNDRED MILL; NOT MUCH VOULME HERE
NAT278	Iowa mill, fluvial	37.8156 107.6181	Y?	NX	OCHER TAILS IN ARRASTRA CRK BELOW MAYFLOW MINE
NAT287	Little Giant, old	37.8061 107.5992	Y	SM	CRUDE HEAP LEACH ON TAILS FROM NAM291 STAMP MILL
NAT290	Little Giant, old	37.8050 107.5992	Y	SM	COURSE TAN TAILS IN CREEK BELOW NAM291 STAMP MILL; HI CC-QTZ-GN-CP
NAT292	Little Giant	37.8086 107.6031	Y	SM	SMALL TAILS FROM LITTLE GIANT MILL M292
NAT378	Vermillion	37.9325 107.5961	Y	SM	YEL-OCHER TAILS,CSE, CRUDE IMPOUND
NAT389	Howardsville S	37.8339 107.6006	Y	NX	RUSTY TAILS AT MILL NAM389, MOST IN ANIMAS?
NAT509	Brooklyn	37.8581 107.7111	Y	SM	POND AT BROOKLYN MINE; TAILS STABLE
NAT524	Ruby Trust	37.8442 107.7519	Y	SX	TAILS AT MILL, SLURRY DOWN HILLSIDE?
NAT528	Red and Bonita	37.8978 107.6450	Y	SM	TAN TAILS FROM R&B MILL M330
NAT529	Gold King old	37.8969 107.6450	Y	SM	GRAY HI PYRITE TAILS
NAT600	Burro Bridge	37.8511 107.7264	?	SX	BURRO MILL TAILS IN FOUNDATION, MOST GONE
NAT602	Lodore	37.8022 107.6728	Y	MX	LODORE MILL TAILS BY MINERAL CREEK
NAT609	Ice Lake	37.8119 107.7817	Y	SX	ICE LAKE STAMP MILL TAILS, VARIABLE TAN TO OCHER

NAT622	Lackawanna	37.8147	107.6525	Y	M	LACKAWANNA MILL OCHER TAILS
NAT628	Fluvial tails	37.9208	107.5597	?	?	FLUVIAL TAILS, ONE MI S OF ANIMAS FORKS
NAT706	Bagley	37.9328	107.5789	Y	MX	BAGLEY MILL TAILS, RUSTY OCHER, SMALL IMPOUND, OTHERS LOST?

Abbreviations: Mill: Y, yes, mill probable; N, no, can not find; ? Questionable;
Tailings Size: LG, large; M, medium, S, small; X, tailings lost.